

**UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF VIRGINIA**

SONY MUSIC ENTERTAINMENT, *et al.*,

Plaintiffs,

v.

COX COMMUNICATIONS, INC., *et al.*,

Defendants.

Case No. 1:18-cv-00950-LO-JFA

DECLARATION OF WILLIAM H. LEHR

1. I, William H. Lehr, hereby declare pursuant to 28 U.S.C. § 1746 that the following statements are true and correct to the best of my personal knowledge and belief:

INTRODUCTION

2. I am a telecommunications and Internet industry economist and consultant with over twenty-five years of experience. I regularly advise senior industry executives and policymakers in the U.S. and abroad on the market, industry, and policy implications of events relevant to the Internet ecosystem, including such topics as the growth of mobile broadband, changing rights regimes for digital media, and the transition to next generation Internet technologies.

3. I am currently a research scientist in the Computer Science and Artificial Intelligence Laboratory (“CSAIL”) at the Massachusetts Institute of Technology (“MIT”), where I participate in a number of multi-disciplinary research projects focused on addressing the mix of technical, business economics, and policy challenges associated with the rise of the Internet as our

global communications infrastructure. My research addresses the convergence of the Internet and telecommunication services and the implications for corporate strategy and public policy. The rise of the Internet as the principal platform for distributing media of all types, and especially entertainment, is a major focus of my work.

4. I am a frequent speaker at international industry, public policy, and academic conferences focused on the economics of the Information and Communications Technology (“ICT”) sector. I have taught graduate-level courses on media, telecommunications, and Internet industry economics at MIT, Columbia University, Cambridge University, and several other universities, and have prepared customized tutorials for executives and senior policymakers in the U.S. and abroad on matters such as telecommunications pricing, applications of advanced economics methods to network economics, and wireless technologies and markets.

5. My research over the last several years has focused on the evolution of Internet infrastructure and the telecommunications industry, with a special focus on the evolution of wireless and broadband services and their regulation. I have published academic research in peer-reviewed journals on a wide range of topics related to the ICT industry, including the economics of technology standard setting, the implications of new broadband technologies, the economic impact of information technologies, and on addressing the challenges of transitioning our regulatory policies in light of the growing importance of the Internet.

6. In addition to my academic work, I provide business and litigation consulting services as an independent contractor on matters of concern to the ICT industries in the United States and abroad. This includes providing expert testimony in civil and regulatory proceedings on a wide range of matters related to the business economics of the ICT sector. I also advise industry

participants in multiple segments of the ICT industries and government policymakers on strategic issues such as technology trends, investment opportunities, business, and marketing strategies.

7. I hold a PhD in Economics from Stanford, an MBA in Finance from the Wharton School, and MSE, BA, and BS degrees from the University of Pennsylvania. My curriculum vitae, which includes a listing of my prior testifying experience, is attached here as **Appendix A**.

8. I have been retained on behalf of Plaintiffs in this case to consider several issues. In connection with my work on this matter, I reviewed a variety of documents, datasets, declarations, and testimonies. The list of materials that I have considered has been set forth in my expert reports in this case. My opinions in this matter are set forth in my expert reports. Portions of those analyses are set forth in this declaration in support of Plaintiffs' Motion for Summary Judgment. I have knowledge of the facts set forth herein based on my personal knowledge or documents and information reviewed in connection with this case and, if necessary, I would and could competently testify thereto if called as a witness in this matter.

9. I am being compensated for my work in this matter at a rate of \$650 per hour. Employees at Analysis Group, Inc., have assisted me with my assignment in this matter, working under my supervision and direction. My compensation is not contingent upon my findings or the outcome of this matter.

ANALYSIS¹

I. Cox Had Economic Incentive to Tolerate Infringing Activity on its Network

A. Benefits Received and Costs Avoided

10. Cox's subscribers pay Cox a monthly service fee that contributes to Cox's revenues and profits. By allowing repeat infringers to continue infringing through Cox's network, Cox retained more customers who purchased Internet access services, either standalone or bundled with other services, than it otherwise would have. Cox earned considerable additional revenue and profit from a subscriber base that included a substantial number of customers who engaged in piracy, including the 57,679 residential and business subscribers ("at-issue subscribers") who were the subject of copyright infringement notices associated with Plaintiffs' works during the period from February 2013 through November 2014. Cox also avoided direct costs that addressing copyright infringement would have incurred.

11. Using Cox's data and an industry average discount rate, I have estimated the average lifetime value of a residential subscriber. I found the lifetime value of a residential subscriber to be [REDACTED] per subscriber.

12. I also used Cox's ticket history data ("Ticket Data"), which contains information on [REDACTED] [REDACTED], to determine the number of subscribers identified in Plaintiffs' notices. Generally speaking, upon receipt of copyright abuse complaints, CATS converts them into CATS "tickets," on which Cox may then take action.

¹ I understand the background facts described in paragraphs 10 – 24 from Cox and third-party documents and deposition testimony provided to me in this case, which I understand are attached as exhibits to the Gould declaration.

13. As to the at-issue residential subscribers for whom Cox provided both monthly subscriber-level billing and payment data (“ICOMS Billing Data”) and Ticket Data, I have calculated that during the Claim Period only (February 1, 2013 through November 26, 2014) [REDACTED] were the subject of *three or more* tickets; and [REDACTED] were the subject of *five or more* tickets.

14. Thus, I found the benefit to Cox from retaining [REDACTED] residential subscribers with *three or more* DMCA tickets during the Claim Period to be [REDACTED], and the benefit from retaining [REDACTED] residential subscribers with *five or more* DMCA tickets during the Claim Period to be [REDACTED]. I have done a similar analysis for at-issue business subscribers, but for simplicity do not include it in this declaration. Though Cox’s expert, W. Christopher Bakewell, criticizes my analysis and has put forth a lower subscriber value, he does not dispute that Cox profited by some financial measure as a result of retaining the subscribers who repeatedly were the subject of Plaintiffs’ infringement notices.

15. By tolerating infringement on its network, Cox avoided direct incremental costs that it would have otherwise incurred. This included the operating expenses associated with implementing an appropriate infringement response policy—e.g., accepting and processing all inbound infringement notices without imposing caps or blacklists, terminating repeat infringing subscribers, handling related inbound customer service calls, and recovering modems for terminated customers, among others.

B. Revenues from Specific “At-Issue” Subscribers in Plaintiffs’ Notices

16. Cox has identified 57,679 at-issue residential and business subscribers who were the subject of Plaintiffs’ notices of infringement during the period from February 2013 through November 2014.



17. I calculated the revenue that Cox received from the subscribers within that set who were repeatedly the subject of Plaintiffs’ notices of infringement, including revenue Cox generated after receiving multiple infringement notices about that subscriber. To do this, I utilized the ICOMS Billing Data (i.e., monthly subscriber-level billing and payment data) produced by Cox and the Cox Ticket Data, as above.

18. As to the Cox at-issue residential subscribers for whom Cox provided both ICOMS Billing and Ticket Data, I have calculated that [REDACTED] were the subject of *three or more* tickets; and [REDACTED] were the subject of *five or more* tickets during the Claim Period (February 1, 2013 through November 26, 2014). Cox billed these specific subscribers more than [REDACTED], and more than [REDACTED], respectively. Cox reports that it collected as revenue [REDACTED] percent of amounts billed to residential customers between 2013 and 2016. I have done a similar analysis for at-issue business subscribers, but for simplicity do not include it in this declaration.

	Subscribers with 3+ DMCA Tickets	Subscribers with 5+ DMCA Tickets
Subscriber Count	[REDACTED]	[REDACTED]
Total Billing Charges (\$, millions)	[REDACTED]	[REDACTED]

19. At the individual subscriber level, the data shows [REDACTED]

[REDACTED]

- 
- 
- Attached to this declaration at Appendix B are Exhibits 4A-4E from my Reply Report. These are graphical illustrations of the above two examples, along with three others, which form a non-exhaustive set of examples.

C. P2P Infringers Likely Purchased Higher-Priced Service Tiers and Cox Earned Greater Revenue on Average From Subscribers With More Infringement Notices

20. During the relevant period, Cox offered its high-speed Internet services in a range of service tiers. For higher prices, Cox subscribers could purchase higher speeds and larger monthly data allowances. As discussed below, peer-to-peer activity consumes substantial bandwidth and is widely known to be used for infringing activity. Cox received additional revenue from subscribers who migrated to higher service tiers to facilitate infringing activity on peer-to-peer networks that consumed more data.

21. According to a presentation and deposition testimony from Cox's consultants, InCode Consulting:

- Cox offered its "Starter" package for a monthly price of \$29, which included a maximum combined upload/download limit of 30 GB per month. Cox's highest-tier "Ultimate" package offering a limit of 400 GB per month was available for a monthly price of \$100, or about \$70 more than the "Starter" package.

- U.S. households consumed on average [REDACTED] per month in high-speed data, while U.S. households that engaged in peer-to-peer activities consumed on average [REDACTED] each month. The average usage for Cox customers that were considered “low”, “medium” and “high” users of peer-to-peer activities were [REDACTED] hours per month, respectively. The average peer-to-peer “session” consumed approximately [REDACTED] of data each hour.
- Cox’s network management data reflects that peer-to-peer usage [REDACTED]
[REDACTED]
[REDACTED]

22. It is widely recognized that peer-to-peer activity often involves copyright infringement. While there may be disagreement over the level of infringement, it is widely recognized that infringement is frequent on peer-to-peer networks.

- Mr. Jorge Fuenzalida, Vice President at InCode Consulting, acknowledged that peer-to-peer file-sharing applications were frequently used for uploading and downloading copyrighted content.
- Mr. Jason Zabek, Manager of Customer Safety at Cox, commented in an internal email that [REDACTED]
- Mr. William Basquin, Vice President of Global Sales Engineering for Sandvine Inc., stated that “peer-to-peer is often used for sharing illegal content.”
- Existing studies also support the understanding that P2P file sharing networks such as BitTorrent are used primarily to pirate copyrighted materials. See, e.g., Price, David. “Sizing the Piracy Universe.” *NetNames/envisional*, September, 2013, p. 3. See also, Mateus, Alexandre M. and Peha, Jon M. “Quantifying Global Transfers of Copyrighted Content Using BitTorrent.” *The 39th Research Conference on Communication, Information and Internet Policy*, 2011, pp. 1-41 and Layton, Robert and Watters, Paul. “Investigation into the Extent of Infringing Content on BitTorrent Networks.” *Internet Commerce Security Laboratory*, 2010, available at http://www.screenassociation.com.au/uploads/reports/bt_report_final.pdf, visited on May 3, 2019

23. Cox’s ICOMS Billing Data and Ticket Data show that subscribers who repeatedly were the subject of Plaintiffs’ infringement notices [REDACTED]

[REDACTED] The ICOMS Billing Data produced by Cox does not include [REDACTED]

██████████ but I was able to review the ██████████

Total Data Charges for an account. I evaluated whether subscribers who were more frequently reported for infringement, based on their number of copyright abuse tickets, were billed more on average than those who received fewer tickets.

24. From 2012-2016, Cox billed the at-issue single-family subscribers with ██████████ or more DMCA tickets between 2012-2014, ██████████ than at-issue subscribers with ██████████ DMCA tickets. Considering just the average ██████████

██████████ Cox billed the at-issue ██████████ DMCA ticket subscribers ██████████

██████████ than the at-issue ██████████ DMCA ticket subscribers. As seen in the table below, there is a ██████████

██████████ As above, Cox reports that it collected as revenue ██████████ percent of amounts billed to residential customers between 2012 and 2016.

	1-2 DMCA Tickets	3-4 DMCA Tickets	5-9 DMCA Tickets	10-19 DMCA Tickets	20+ DMCA Tickets
Average Monthly Data Recurring Charge (MRC)	██████████	██████████	██████████	██████████	██████████
Average Monthly Total Data Charge	██████████	██████████	██████████	██████████	██████████
Subscriber Count	██████████	██████████	██████████	██████████	██████████

William H. Lehr, Ph.D.
August 30, 2019

Appendix A***WILLIAM HERNDON LEHR****Contact information:*

Home/Office	Alternate Office
94 Hubbard Street Concord, MA 01742 Tel: 978-287-0525 Cellular: 978-618-3775 Email: wlehr@mit.edu	Massachusetts Institute of Technology 32 Vassar Street (32-G532) Cambridge, MA 02139 Tel: 617-258-0630 Website: http://csail.mit.edu/~wlehr

Biographical Description

Dr. William Lehr is a telecommunications and Internet industry economist and consultant with over twenty-five years of experience. He regularly advises senior industry executives and policymakers in the U.S. and abroad on the market, industry, and policy implications of events relevant to the Internet ecosystem. He is a research scientist in the Computer Science and Artificial Intelligence Laboratory (CSAIL) at the Massachusetts Institute of Technology, currently engaged in a number of multidisciplinary research projects within the Advanced Networking Architecture Group in CSAIL. Dr. Lehr's research focuses on the economics and regulatory policy of the Internet infrastructure industries. He teaches courses on the economics, business strategy, and public policy issues facing telecommunications, Internet, and eCommerce companies, and is a frequent speaker at international industry and academic conferences. He is the author of numerous publications on such topics as the measurement of economic impacts of Information technologies, the economics of technical standard setting, the pricing of Internet services, and the implications of commercializing novel Internet and wireless technologies for industry structure and regulatory policy.

In addition to his academic research, Dr. Lehr provides litigation, economic, and business strategy consulting services for firms in the information technology industries in the U.S. and abroad. Dr. Lehr has advised information technology companies on strategic marketing, pricing, financial planning, and competitive strategy; and government agencies in the United States and abroad on telecommunications and Internet policy matters. Dr. Lehr has prepared expert witness testimony for both private litigation and for regulatory proceedings before the FCC, before numerous state commissions, and for a number of regulatory agencies abroad.

Dr. Lehr holds a PhD in Economics from Stanford (1992), an MBA from the Wharton Graduate School (1984), and MSE (1984), BS (1979) and BA (1979) degrees from the University of Pennsylvania.

Appendix A

WILLIAM HERNDON LEHR **Curriculum Vitae**

EDUCATION

Ph.D., Economics, Stanford University, 1992.

M.B.A., with distinction, The Wharton School, University of Pennsylvania, 1984.

M.S.E., Chemical Engineering, University of Pennsylvania, 1984.

B.S., Chemical Engineering, *cum laude*, University of Pennsylvania, 1979.

B.A., European History, *magna cum laude*, University of Pennsylvania, 1979.

Academic Honors: Graduate Student Research Award, Telecommunications Policy Research Conference, 1991; Lynde and Harry Bradley Foundation Fellowship, 1990; Stanford Fellowship, 1987

PROFESSIONAL EXPERIENCE

Computer Science and Artificial Intelligence Laboratory (CSAIL), Massachusetts Institute of Technology (Cambridge, MA), Research Scientist, July 2006-present; previously, in Center for Technology, Policy and Industrial Development, MIT, 1997- June 2006. Working with MIT Internet Telecoms Convergence Consortium (1997-2004); Communications Futures Program (2004-2017); Advanced Network Architecture Group (2006-present).

Graduate School of Business, Columbia University (New York, NY), Associate Research Scholar of Finance and Economics, 1997-2002; Assistant Professor of Finance and Economics, July 1991 to December 1996.

RAND Corporation (Santa Monica, CA), Graduate Student Intern, Summer 1990.

Economic Analysis Group, Ltd. (Washington, DC), Senior Consultant, 1985-1987.

M.C.I. Telecommunications (Washington, DC), Manager of Financial Analysis, 1985; Senior Financial Analyst, 1984.

Office of Management and Budget, National Security Division (Washington, DC), Graduate Student Intern, Summer 1983.

Putnam, Hayes and Bartlett (Cambridge, MA), Research Associate 1980-1982.

TEACHING EXPERIENCE

Communications & Information Policy
Internet Pricing and Quality of Service
Internet Commerce

Appendix A

Internet Economics 101
Internet Telephony Tutorial
Internet Commerce Video Course
Economics of Telecommunications Pricing
Economics and Strategy in Media Industries
Economics of Strategic Management
Managerial Economics
Telecommunications: Technologies and Policies in the Networked Digital World
Theory of the Firm (teaching assistant for Paul Milgrom)
Wireless Broadband in the Developing World

PAPERS and PUBLICATIONS

Lehr, W. (2019), "Economics of Spectrum Sharing, Valuation and Secondary Markets," in C. Papadias, T. Ratnarajah and D. Stock (eds.), *Spectrum Sharing: the Next Frontier in Wireless Networks*, New York: Wiley, 2019 (forthcoming).

Lehr, W. (2019), "5G and the Future of Broadband," in G. Kneips & V. Stocker (eds.), *The Future of the Internet - Innovation, Integration, and Sustainability*, Baden-Baden: Nomos, 2019 (forthcoming).

Lehr, W. (2019), "The Changing Context for Broadband Evaluation," in K. Mossberger, E. Welch, and Y. Wu (eds), *Transforming Everything? Evaluating broadband's impacts across policy areas*, Oxford: Oxford University Press, 2019 (forthcoming).

"Communications Act 2021," (2018) with D. Sicker, *Journal of High Technology Law*, Volume 18, Number 2 (2018) 270-330.

"SMAP: A Scalable and Distributed Architecture for Dynamic Spectrum Management," (2018) with P. Karimi, D. Raychaudhuri and I. Seskar, IEEE DySPAN 2018, Seoul, Korea, October 2018

"When cyber threats loom, what can state and local governments do?", (2018) with J. Wolff, *Georgetown Journal of International Affairs*, Fall 2018.

"Whither the Public Internet?" (2018) with D. Clark, S. Bauer, A. Berger and P. Richter, 46th TPRC: (2018), TPRC46: The 46th Research Conference on Communication, Information, and Internet Policy 2018, available at <https://ssrn.com/abstract=3141969>.

"Spectrum Valuation: Implications for Sharing and Secondary Markets," (2018) with M. Gomez, M. Weiss, and G. McHenry, TPRC46: The 46th Research Conference on Communication, Information, and Internet Policy 2018, available at <https://ssrn.com/abstract=3142182>.

Appendix A

"Telecom Déjà Vu: A Model for Sharing in Broadband Access," (2018), with D. Sicker, TPRC46: The 46th Research Conference on Communication, Information, and Internet Policy 2018, available at <https://ssrn.com/abstract=3142172>.

"Measuring Mobile Broadband Performance," (2018) with S. Bauer, TPRC46: The 46th Research Conference on Communication, Information, and Internet Policy 2018, available at <https://ssrn.com/abstract=3138610>.

"Roles for Policy-Makers in Emerging Cyber Insurance Industry Partnerships," (2018) with J. Wolff, TPRC46: Research Conference on Communications, Information and Internet Policy, American University, Washington, DC, September 21-22, 2018, abstract available at <https://ssrn.com/abstract=3141409>.

"Future of Broadband Competition in a 5G World" (2018), White paper, available at <http://dx.doi.org/10.2139/ssrn.3240191>.

"Analysis of Proposed Modifications to the CBRS PAL License Framework," Ex parte comment submitted to Federal Communications Commission in the Matter of Promoting Investment in the 3550-3700 MHz Band, Docket 17-258, December 2017.

ICT-centric economic growth, innovation and job creation, co-editor with Ahmad Sharafat, ITU Publishing: Geneva, October 2017.

"ICT Engines for Sustainable Development," with A. Sharafat, in A. Sharafat & W. Lehr (eds.), ICT-centric economic growth, innovation and job creation, Geneva, Switzerland: International Telecommunications Union (ITU), 2017, available at <http://handle.itu.int/11.1002/pub/80fc3264-en>

"Degrees of Ignorance About the Costs of Data Breaches: What Policymakers Can and Can't Do About the Lack of Good Empirical Data," with Josephine Wolff, 45th Research Conference on Communications and Internet Policy, Alexandria, VA, September 2017.

"The growing complexity of content delivery networks: Challenges and implications for the Internet ecosystem," with V. Stocker, G. Smaragdakis, and S. Bauer, *Telecommunications Policy*, Vol 41 (10) 1003-1016, 2017, <https://doi.org/10.1016/j.telpol.017.02.004>.

"Would you like your Internet with or without video?" with D. Sicker, *Journal of Law, Technology & Policy*, vol 2017 (Issue 1 Spring), available at <http://illinoisjltip.com/journal/wp-content/uploads/2017/05/Lehr.pdf>.

"Ex-post mitigation strategies for theft of non-financial data," with J. Wolff, TPRC44, September 2016, Alexandria, VA, available at [available at SSRN: https://ssrn.com/abstract=2756842](https://ssrn.com/abstract=2756842) or <http://dx.doi.org/10.2139/ssrn.2756842>

Appendix A

"Improving the Measurement and Analysis of Gigabit Broadband Networks," with S. Bauer and M. Mou, TPRC44, September 2016, available at <http://dx.doi.org/10.2139/ssrn.2757050>.

"Content may be King, but (Peering) Location matters: A Progress Report on the Evolution of Content Delivery in the Internet," with V. Stocker, G. Smaragdakis, and S. Bauer, EuroITS2016, Cambridge University, Cambridge UK, September 2016, available at <http://people.csail.mit.edu/gsmaragd/publications/ITS2016/>

"An Overview of Dynamic Spectrum Sharing: Ongoing Initiatives, Challenges, and a Roadmap for Future Research," with S. Bhattarai, J. Park, B. Gao, and K. Bian, IEEE Transactions on Cognitive Communications and Networking, Vol. 2, No. 2, June 2016, 110-28.

"Spectrum License Design, Sharing, and Exclusion Rights," Journal of Law, Technology, & Policy, Vol. 2016, Spring, No. 1, 1-33.

"Interconnection in the Internet: peering, interoperability, and content delivery," with D. Clark and S. Bauer, Chapter 16 in J. Bauer and M. Latzer (eds) *Handbook on the Economics of the Internet*, Edward Elgar: Northampton MA, 2016.

"Socio-Technical Considerations for Spectrum Access System (SAS) Design," with M. Weiss, A. Acker, and M. Gomez (2015), IEEE DySPAN 2015.

"Gigabit Broadband, Interconnection Propositions, and the Challenge of Managing Expectations," with S. Bauer and S. Hung, TPRC2015, Alexandria, VA, September 2015.

"The Road to an Open Internet is Paved with Pragmatic Disclosure & Transparency Policies," with E. Kenneally and S. Bauer, TPRC2015, Alexandria, VA, September 2015.

"Reliability and the Internet Cloud," C.Yoo and J-F. Blanchette (eds), in *Regulating the Cloud: Policy for Computing Infrastructure*, MIT Press: Cambridge, MA, 2015.

"Measurement and Analysis of Internet Interconnection and Congestion," with D. Clark, S. Bauer, K. Claffy, A. Dhamdhere, B. Huffaker, and M. Luckie, Journal of Information Policy, Vol 4 (2014).

"Benefits of Competition in Mobile Services," a white paper submitted as Ex Parte to FCC in the matter of Wireless Telecommunications Bureau Seeks Comment on the State of Mobile Wireless Competition, WT Docket No. 13-135, 24 March 2014, available at <http://apps.fcc.gov/ecfs/document/view?id=7521094963>.

Appendix A

"Toward More Efficient Spectrum Management: New Models for Protected Shared Access," (WG Chair), a White Paper prepared by the MIT Communications Futures Program Spectrum Working Group, submitted to FCC's 3.5GHz proceeding (Docket #12-354), available at <http://apps.fcc.gov/ecfs/comment/confirm?confirmation=201437236301>.

"Small cells and the mobile broadband ecosystem," with M. Oliver, Euro ITS2014, Brussels, June 2014, available at <http://econpapers.repec.org/paper/zbwitse14/101406.htm>.

"PALs as Options to Exclude GAA," Reply Comments submitted in the matter of Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band, GN Docket 12-354, August 15, 2014, available at <http://apps.fcc.gov/ecfs/document/view?id=7521763142>.

"The Mistake of One-Sided Open Internet Policy," a white paper, prepared with support from the American Cable Association, July 2014, available at <http://apps.fcc.gov/ecfs/document/view?id=7521683605>.

"Mobile Broadband: toward a sustainable ecosystem," (with M. Montpetit), a White Paper prepared by the MIT Communications Futures Program Mobile Broadband Working Group, May 2014, available at http://cfp.mit.edu/publications/CFP_Papers/CFP%20Mobile%20Broadband%20White%20Paper%20May%202014.pdf

"The NEBULA Future Internet Architecture," with Anderson, T., K. Birman, R. Broberg, M. Caesar, D. Comer, C. Cotton, M. Freedman, A. Haeberlen, Z. Ives, A. Krishnamurthy, B. Loo, D. Mazieres, A. Nicolosi, J. Smith, I. Stoica, R. Renesse, M. Walsh, H. Weatherspoon, and C. Yoo forthcoming in *The Future Internet: Future Internet Assembly 2013*, A. Galis and A. Gavras (eds), Lecture Notes in Computer Science – Volume 7858, Springer: New York, 2013.

"MobilityFirst, LTE and the Evolution of Mobile Networks," with R. Yates, IEEE DySPAN2012, Bellevue, Washington, October 2012

"Enforcement in Dynamic Spectrum Access Systems," with M. Weiss, L. Cui, and M. Altamini, TPRC2012, Alexandria, VA, September 2012

"A Data Driven Exploration of Broadband Traffic Issues: Growth, Management, and Policy," with Steve Bauer and David Clark, TPRC2012, Alexandria, VA, September 2012

"Reliability and the Internet Cloud," paper prepared for *Workshop on Cloud Computing: Economic and Regulatory Implications*, University of Pennsylvania, February 24, 2012 (paper June 2012).

Appendix A

"Measuring Broadband Performance when Broadband is the New PSTN," with D. Clark and S. Bauer, MITAS Working Paper, *The End of the Phone System Workshop*, University of Pennsylvania, May 2012

"Measuring the Internet: the data challenge," Organization for Economic Cooperation and Development (OECD) Digital Economy Working Paper 184, ISSN 2071-6826, April 2012.

"Mobile Broadband Growth, Spectrum Scarcity, and Sustainable Competition," with John Chapin, *39th Research Conference on Communications, Information and Internet Policy* (www.tprcweb.com), Alexandria, VA, September 2011.

"Assessing broadband reliability: Measurement and policy challenges," with Steven Bauer, Mikko Heikkinen, and David Clark, *39th Research Conference on Communications, Information and Internet Policy* (www.tprcweb.com), Alexandria, VA, September 2011.

"Interconnection in the Internet: the policy challenge," with David Clark and Steven Bauer, *39th Research Conference on Communications, Information and Internet Policy* (www.tprcweb.com), Alexandria, VA, September 2011.

"Powerboost," with Steven Bauer and David Clark, *Proceedings of IEEE HomeNets '11*, Toronto, Canada, August 2011.

"Clouds, Cable And Connectivity: Future Internets And Router Requirements," with Robert Broberg, Andrei Agapi, Ken Birman, Douglas Comer, Chase Cotton, Thilo Kielmann, Robbert VanRenesse, Robert Surton, and Jonathan Smith, *Proc. 2011 Cable Connection Spring Technical Conference*, June 14-16, Chicago, IL.

"SCADA for the Rest of Us: Unlicensed Bands Supporting Long-Range Communications," with John Chapin, *38th Research Conference on Communications, Information and Internet Policy* (www.tprcweb.com), Alexandria, VA, October 1-2, 2010.

"Understanding Broadband Speed Measurements," with Steve Bauer and David Clark, MITAS Working Paper, June 2010, available at: http://mitas.csail.mit.edu/papers/Bauer_Clark_Lehr_Broadband_Speed_Measurements.pdf.

"On the convergence of wired and wireless access network architectures," with John Chapin, *Internet Economics and Policy*, 22 (2010) 33-41.

"Mobile Broadband and Implications for Broadband Competition and Adoption," a white paper prepared on behalf of *Broadband for America*, November 2009.

Appendix A

"Broadband microfoundations: the need for traffic data," with Stephen Bauer and David Clark, *Beyond Broadband Access* conference, NewAmerica Foundation, Washington DC, September 22-24, 2009.

"The Evolution of Internet Congestion," with Stephen Bauer and David Clark, paper prepared for 37th Research Conference on Communication, Information and Internet Policy (www.tprcweb.com),^[1]_[SEP] Arlington, VA, September 2009.

"Hybrid Wireless Broadband," with John Chapin, paper prepared for 37th Research Conference on Communication, Information and Internet Policy (www.tprcweb.com),^[1]_[SEP] Arlington, VA, September 2009.

"Rethinking wireless broadband platforms," with John Chapin, invited paper presented at *Wireless Technologies: Enabling Innovation and Growth*, Georgetown Center for Business and Public Policy, Washington DC, April 17, 2009.

"Internet Policy – A Mix of Old and New Challenges," with Lorenzo Pupillo, in *Internet Policy and Economics: Challenges and Perspectives*, W. Lehr and L. Pupillo (editors), Springer: New York, 2009.

"The role of Unlicensed in Spectrum Reform," in *Internet Policy and Economics: Challenges and Perspectives*, W. Lehr and L. Pupillo (editors), Springer: New York, 2009.

Internet Policy and Economics: Challenges and Perspectives, co-edited with Lorenzo Pupillo, Springer: New York, 2009.

"Measurement and Assessment of Broadband Availability," with Tony Smith-Grieco, Report prepared for the John Adams Innovation Institute at the Massachusetts Institute of Technology, January 2009.

"Public Safety Radios Need to Pool Spectrum," with Nancy Jesuale, *IEEE Communications Magazine*, March 2009.

"The Growing Complexity of Internet Interconnection," with Peyman Faratin, David Clark, Steven Bauer, Patrick Gilmore, and Arthur Berger, *Communications & Strategies*, No. 72, 4th Quarter 2008, pages 1-21.

"Spectrum Pooling for Next Generation Public Safety Radio Systems," with Nancy Jesuale, prepared for IEEE Dynamic Spectrum Access Networks (DySPAN08) Conference, Chicago, October 14-17, 2008.

"Running on Empty: the challenge of managing Internet addresses," with Tom Vest and Eliot Lear, prepared for the 36th Research Conference on Communication, Information, and Internet Policy, George Mason University, Arlington, VA, September 26-28, 2008.

Appendix A

"Broadband Metrics Best Practices: Review and Assessment," with Tony Smith-Grieco and Grace Rusi Woo, report prepared for Massachusetts Technology Collaborative/John Adams Innovation Institute (MTC/JAII), February 2008.

"Measuring Broadband: Improving Communications Policymaking through Better Data Collection," with Kenneth Flamm, John Horrigan, and Amy Friedlander, Pew Internet & American Life Project, Washington, DC, November 2007.

"Coordinating User Behavior and Device Behavior in Wireless Grids," with Lee McKnight and James Howison, in *Cognitive Wireless Networks*, edited by Fitzek, F. and M. Katz, Springer: The Netherlands, 2007.

"Study of Market-based Exclusive Spectrum Rights," with Adrian Foster, Martin Cave, and Robert Jones, report prepared for Industry Canada, August 2007.

"Complexity of Internet Interconnections: Technology, Incentives and Implications for Policy," with P. Faratin, D. Clark, P. Gilmore, and A. Berger, paper prepared for 35th Annual Telecommunications Policy Research Conference, George Mason University, September 2007.

Special Issue on Network Neutrality, co-edited with Jon Peha and Simon Wilkie, *International Journal of Communication* (volume 1, 2007), August 2007 (available at <http://ijoc.org/ojs/index.php/ijoc/issue/view/1>).

"Introduction: The State of the Debate on Network Neutrality," with Jon Peha and Simon Wilkie, *International Journal of Communication* (volume 1, 2007), August 2007, pages 8-20 (available at <http://ijoc.org/ojs/index.php/ijoc>).

"Scenarios for the Network Neutrality Arms Race," with Marvin Sirbu, Jon Peha, and Sharon Gillett, *International Journal of Communication* (volume 1, 2007), August 2007, pages 8-20 (available at <http://ijoc.org/ojs/index.php/ijoc>) (paper originally presented at the 34th Annual Telecommunications Policy Research Conference, George Mason University, September 2006.)

"The Effects of Broadband Deployment on Output and Employment: A Cross-sectional Analysis of U.S. Data," with Robert Crandall and Robert Litan, *Issues in Economic Policy*, The Brookings Institution, Number 6, July 2007 (available at: <http://www.brookings.edu/views/papers/crandall/200706litan.htm>)

"The path to market success for dynamic spectrum access technologies," with John Chapin, *IEEE Communications Magazine*, May 2007.

"Time-limited Leases for Innovative Radios," with John Chapin, *IEEE Communications Magazine*, June 2007.

Appendix A

"Overlay Networks and Future of the Internet," with David Clark, Steve Bauer, Peyman Faratin, Rahul Sami, and John Wroclawski, *Communications and Strategies*, no. 63 (3rd Quarter 2006) 1-21.

"Measuring Broadband's Economic Impact," with Sharon Gillett, Carlos O'sorio, and Marvin Sirbu, *Broadband Properties*, vol. 24, no. 12 (Revised January 2006) 12-24.

"Managing Access to a Spectrum Commons," with Jon Crowcroft, paper prepared for IEEE DySPAN Conference, Baltimore, MD, November 2005.

"The Growth of Internet Overlay Networks: Implications for Architecture, Industry Structure and Policy," with David Clark, Peyman Faratin, Rahul Sami, and John Wroclawski, paper presented at the 33rd Annual Telecommunications Policy Research Conference, George Mason University, September 2005.

"Evolving Wireless Access Technologies for Municipal Broadband," with Marvin Sirbu and Sharon Gillett, *Government Information Quarterly*, 23 (2006) 480-502.

"Wireless is Changing the Policy Calculus for Municipal Broadband," with Marvin Sirbu and Sharon Gillett, *Government Information Quarterly*, 23 (2006) 435-453

"Measuring Broadband's Economic Impact," with Sharon Gillett, Marvin Sirbu, and Carlos Osorio, paper presented at the 33rd Annual Telecommunications Policy Research Conference, George Mason University, September 2005.

"The Role of Unlicensed in Spectrum Reform," draft mimeo, Massachusetts Institute of Technology, March 2005.

"Broadband Open Access: Lessons from Municipal Network Case Studies," with Marvin Sirbu and Sharon Gillett, paper presented at the 32nd Annual Telecommunications Policy Research Conference, George Mason University, September 2004.

"The Municipal Role in U.S. FTTH Market Growth," with Sharon Gillett and Carlos Osorio, prepared for the FTTH Council's 3rd Annual FTTH Conference and Expo, October 4-6, 2004, Orlando, FL.

"Municipal Electric Utilities' Role in Telecommunications Services," with Sharon Gillett and Carlos Osorio, *Telecommunications Policy*, vol 30, issue 8-9 (September-October 2006) 464-480.

"Municipal Wireless Broadband: Policy and Business Implications of Emerging Access Technologies," with Marvin Sirbu and Sharon Gillett, paper prepared for

Appendix A

"Competition in Networking: Wireless and Wireline," London Business School, April 13-14, 2004.

"Wireless Broadband: Coming to a Town Hall Near You?" MIT Technology Insider, August 2004.

"Local Government Broadband Initiatives," with Sharon Eisner Gillett and Carlos Osorio, *Telecommunications Policy*, 28 (August 2004) 537-558.

"Economic Case for Dedicated Unlicensed Spectrum Below 3GHz," paper prepared for New America Foundation Conference, April 2004.

"TELRIC and the Cost of Capital," with R. Glenn Hubbard, white paper prepared on behalf of AT&T for *ex parte* submission to the FCC, December 2003.

"Coordinating User and Device Behavior in Wireless Grids," with Lee McKnight and James Howison, draft paper, Syracuse University, October 2003.

"Local Government Broadband Initiatives," with Sharon Eisner Gillett and Carlos Osorio, paper prepared for the 31st Annual Telecommunications Policy Research Conference, George Mason University, September 2003.

"Economic Case for Voluntary Structural Separation," with R. Glenn Hubbard, paper prepared for the 31st Annual Telecommunications Policy Research Conference, George Mason University, September 2003.

"Software Radio: Implications for Wireless Services, Industry Structure, and Public Policy," with Sharon Gillett and Fuencisla Merino, *Communications and Strategies*, IDATE, Issue 49 (1st Quarter 2003) 15-42.

"Wireless Internet Access: 3G vs. WiFi?," with Lee McKnight, *Telecommunications Policy*, 27 (2003) 351-370.

"Local Government Stimulation of Broadband: Effectiveness, E-Government, and Economic Development," with David Clark, Sharon Gillett, Marvin Sirbu, and Jane Fountain, A White Paper Prepared from A Proposal to the U.S. National Science Foundation Program on Digital Government, Massachusetts Institute of Technology, November 7, 2002.

"Stimulating Investment and the Telecommunications Act of 1996," with Robert Willig, John Bigelow, and Stephen Levinson, white paper prepared on behalf of AT&T, October 2002.

Cyber Policy and Economics in an Internet Age, co-edited with Lorenzo Pupillo, Kluwer Academic Press: Norwell, MA, November 2002.

Appendix A

"Optical Networks and the Future of Broadband Services," with Pedro Ferriera and Lee McKnight, *Technological Forecasting and Social Change*, 69 (2002) 741-758.

"Show Me the Money: Contracts and Agents in Service Level Agreement Markets," with Lee McKnight, *info*, vol. 4, no. 1 (2002) 24-36.

"Promoting Broadband Investment and Avoiding Monopoly," with Robert Hall, white paper prepared on behalf of AT&T, February 2002.

"Best Effort versus Spectrum Markets: Wideband and Wi-Fi versus 3G MVNOs?" with Raymond Linsenmayer and Lee McKnight, forthcoming in *Proceedings of the 29th TPRC: Research Conference on Information, Communication, and Internet Policy*, edited by Shane Greenstein and Lorrie Cranor.

"The Disruptive User – Internet Appliances and the Management of Complexity," with Sharon Gillett, David Clark, and John Wroclawski, *BT Technology Journal*, Vol. 19, No. 4 (October 2001) 40-45.

"Rescuing Competition to Stimulate Telecom Growth," with Robert Hall, white paper prepared on behalf of AT&T, October 2001.

"Do Appliances Threaten Internet Innovation?" with Sharon Gillett, David Clark, and John Wroclawski, *IEEE Communications Magazine*, vol. 39, no. 10 (October 2001) 46-51.

"No Optical Illusion: A market for Bandwidth is Emerging," with Lee McKnight, *WorldLink*, World Economic Forum, May/June 2001.

Book Review of *Letting Go: Deregulating the Process of Regulation* by Alfred Kahn, *Journal of Economic Literature*, vol. XXXIX (September 2001) 943-944.

"Competition in Telecommunications and Economic Growth," with Jim Glassman, report prepared for TechCentral Station, July 2001.

"The Economics of the Tauzin-Dingell Bill: Theory and Evidence," with Jim Glassman, report prepared for TechCentral Station, June 2001.

"Assessing the Cost of Capital for a Standalone Transmission Company," with Michael Cragg and Ron Rudkin, *The Electricity Journal*, Volume 14, Issue 1, January-February 2001, Pages 80-88.

Internet Telephony, (co-edited with David Clark and Lee McKnight), Cambridge, MA: MIT Press, 2001.

Appendix A

"A New Theory of the Internet Firm," in Creative Destruction: Business Strategies for the Global Internet, edited by Lee McKnight, Paul Vaaler, and Raul Katz, Cambridge, MA: MIT Press, 2001.

"A Taxonomy of Internet Appliances," with Sharon Gillett, David Clark, and John Wroclowski, paper presented to the Twenty-Eighth Annual Telecommunications Policy Research Conference, September 25-27, 2000, Alexandria, VA

"A Broadband Access Market Framework: Towards Consumer Service Level Agreements," with Lee McKnight, paper presented to the Twenty-Eighth Annual Telecommunications Policy Research Conference, September 25-27, 2000, Alexandria, VA

"The Tax on Talking Is a Luxury We Can No Longer Afford," with R. Glenn Hubbard, paper prepared for submission to the U.S. Senate, May 2000.

"Telecommunications, the Internet, and the Cost of Capital," with R. Glenn Hubbard, in The Internet Upheaval, edited by Ingo Vogelsang and Ben Compaine, MIT Press: Cambridge, 2000.

"Rapporteur's Report: Next Generation Internet Policy Workshop," MIT Internet & Telecoms Convergence Consortium, http://itc.mit.edu/rpcp/NGIPolicy/rap_final.html, September 1999.

"Provisioning for Bursty Internet Traffic: Implications for Industry Structure," with David Clark, paper presented to Workshop on Internet Service Quality Economics, Massachusetts Institute of Technology, December 2-3, 1999, Cambridge, MA

"Availability of Broadband Internet Access: Empirical Evidence," with Sharon Gillett, paper presented to the Twenty-Seventh Annual Telecommunications Policy Research Conference, September 25-27, 1999, Alexandria, VA

"Telecommunication Regulation in the United States and Europe: The Case for Centralized Authority," with Thomas Kiessling," in *Competition, Regulation and Convergence: Trends in Telecommunications Policy Research*, S. E. Gillett and I. Vogelsang (Eds.), Lawrence Erlbaum Associates, Mahwah, NJ, 1999.

"The Flexible Specialization Path of the Internet," with Petros Kavassalis, in *Convergence in Communications and Beyond*, edited by Erik Bohlin, Karolina Brodin, Anders Lundgren, and Bertil Thorngren, Amsterdam: Elsevier Science, October, 2000.

"Next Generation Bandwidth Markets," with Lee McKnight, Communications & Strategies, Number 32, 4th Quarter 1998, 91-106.

Appendix A

"Forces for Integration and Disintegration in the Internet," with Petros Kavassalis, Communications and Strategies, Number 30, 2nd Quarter 1998, 135-154.

"Computer Use and Productivity Growth in Federal Government Agencies, 1987-92", with Frank Lichtenberg, Journal of Industrial Economics, Volume XLVI, Number 2, June 1998, 257-279.

"Understanding Vertical Integration in the Internet," mimeo, paper presented to Euro CPR '98 Conference, Venice, April 1998.

"Improving Local Exchange Competition: Regulatory Crossroads," with R. Glenn Hubbard, mimeo, Columbia University, February 1998.

"Information Technology and Its Impact on Productivity: Firm-level Evidence from Government and Private Data Sources, 1977-1993," with Frank Lichtenberg, Canadian Journal of Economics, volume 32, No. 2, April 1999, pages 335-362.

"The Political Economy of Congestion Charges and Settlements in Packet Networks," with Martin Weiss, Telecommunications Policy, 20(3), April 1996, pages 219-31.

"Compatibility Standards and Industry Competition: Two Case Studies", Economics of Innovation and New Technology, 4(2), 1996, pages 97-112.

"Compatibility Standards and Interoperability: Lessons from the Internet", in Standards Policy for Information Infrastructure, edited by B. Kahin and J. Abbate, Harvard Information Infrastructure Project, Cambridge MA: MIT Press, 1995.

Quality and Reliability of Telecommunication Infrastructure (editor), Hillsdale, NJ: Lawrence Erlbaum Associates, 1995.

"The Quality of Complex Systems and Industry Structure", with Nicholas Economides, in Quality and Reliability of Telecommunication Infrastructure, edited by William Lehr, Hillsdale, NJ: Lawrence Erlbaum Associates, 1995.

"Repeated Contract Negotiations with Private Information: Comment," Japan and the World Economy, 7(4), November 1995, pages 473-74.

"Quality Choices in a Network of Networks", in *Private Networks and Public Objectives*, edited by E. Noam and A. NiShúilleabháin, North Holland: New York, 1996.

"ISDN in the U.S.A.: Is it Arriving at Last?", in *ISDN: An International Comparison of Trends in the USA, Japan, Singapore and Europe*, Final Report to the ISDN Commission of North Rhine-Westphalia, May 1996.

Appendix A

"Compatibility Standards and the Internet", Graduate School of Business, Columbia University, working paper, September 1992.

"Standardization: Understanding the Process", Journal of the American Society for Information Science, vol 43, no 8 (September 1992) 550-555.

"Voluntary Standards, Multiple Markets, Standards Institutions, and Industry Structure", Graduate School of Business, Columbia University, working paper, July 1992.

"ISDN and the Small User: Regulatory Policy Issues", with Roger Noll, in Integrated Broadband Networks: the Public Policy Issues, edited by Martin Elton, North-Holland, New York, 1991, 147-178.

"Incremental Costs and the Efficient Pricing of Local Exchange Services: A Synopsis of the Incremental Cost Conference", Center for Economic Policy Research Working Paper #175, Stanford University, January 1990.

"Vertical Integration in the Cable Television Industry: the Issue of Content/Carrier Separation", WD-5100-MF, RAND Corporation, Santa Monica, CA, August 1990.

"ISDN: an Economists' Primer to a New Telecommunications Technology", working paper, February 1989.

"Economics of Anticipatory Standard Setting", working draft, presented at the European Association of Research in Industrial Economics (E.A.R.I.E.) Conference, Chania, Crete, September 1994.

"Political Economics of Voluntary Standard Setting", Graduate School of Business, Columbia University, working draft, January 1992.

Appendix A

Expert Testimony and Testifying Experience

Dr. William H. Lehr

Expert Report of William H. Lehr, Ph.D., on behalf of Plaintiffs, In the matter of UMG Recordings, Inc. et al. (Plaintiffs) v. Grande Communications Networks LLC and Patriot Media Consulting, LLC (Defendants), Before the District Court of Western District of Texas, Austin Division, Civil Action No. 1:17-cv-365, July 2018.

Expert Report of William H. Lehr, Ph.D., on behalf of Defendants, In the matter of CamSoft Data Systems, Inc. v. Southern Electronics Supply, Inc. and Active Solutions, LLC, et al., Before the District Court of East Baton Rouge Parish, Louisiana, 19th Judicial District, Docket No. 582,741 Sec. D, April 20, 2018.

Expert Report of William H. Lehr, on behalf of Plaintiffs, In the matter of Charter Advanced Services (MN), LLC et. al. (Plaintiffs) v. Beverly Jones Heydinger, et. al. (Defendants), Before the United States District Court, District of Minnesota, Case No. 15-cv-3935 (SRN/KMM), April 29, 2016.

Expert Report of William H. Lehr, PhD on Behalf of Plaintiff, In the matter of BMG Rights Management (US) LLC and Round Hill Music LP (plaintiffs) v. Cox Enterprises, Cox Communications, and CoxCom LLC (defendants), Before the United States District Court, Eastern District of Virginia, Case No. 1:4-cv-1611 (LOG/JFA), June 2015.

Appendix B

Exhibit 4A

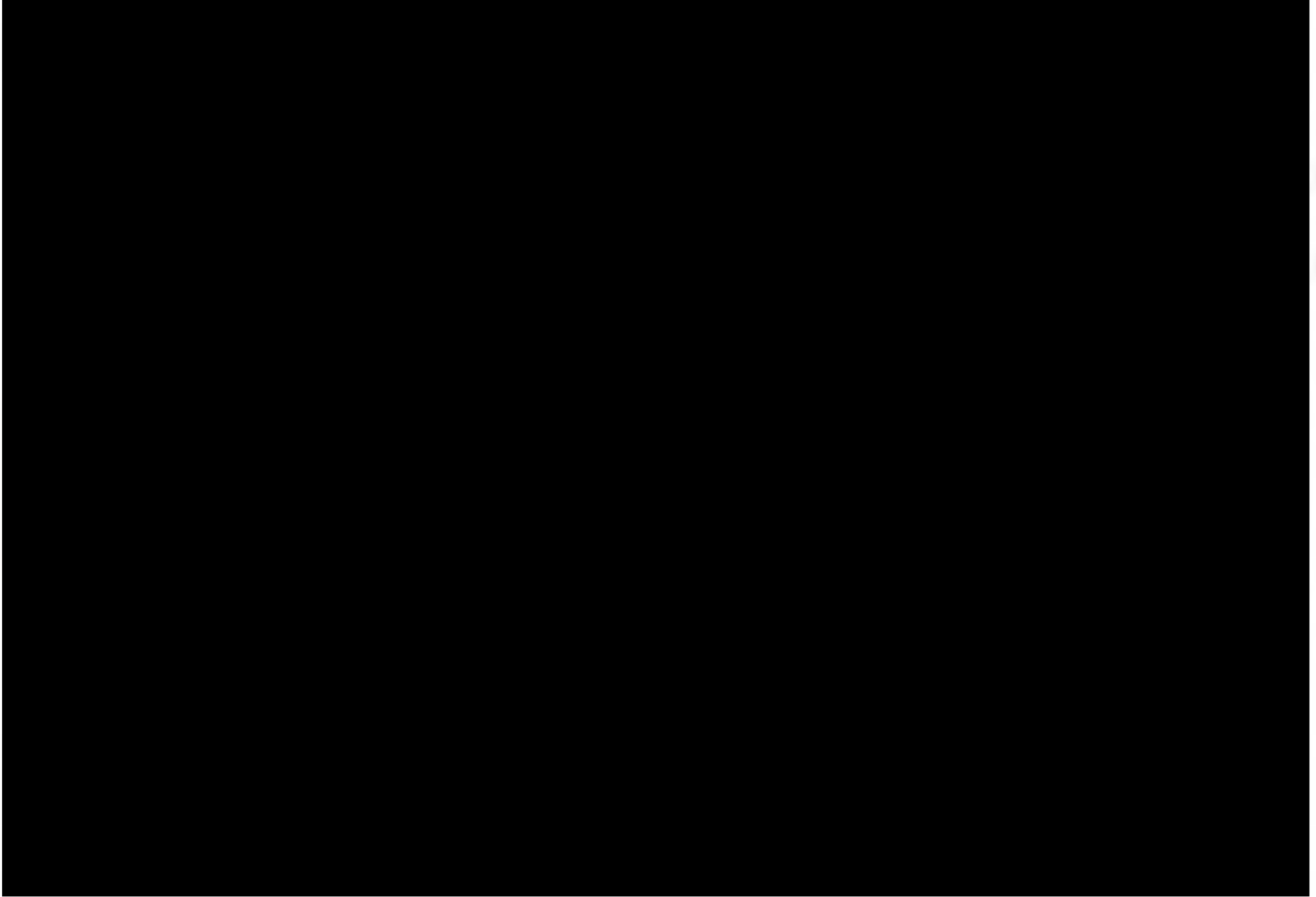


Exhibit 4B



Exhibit 4C

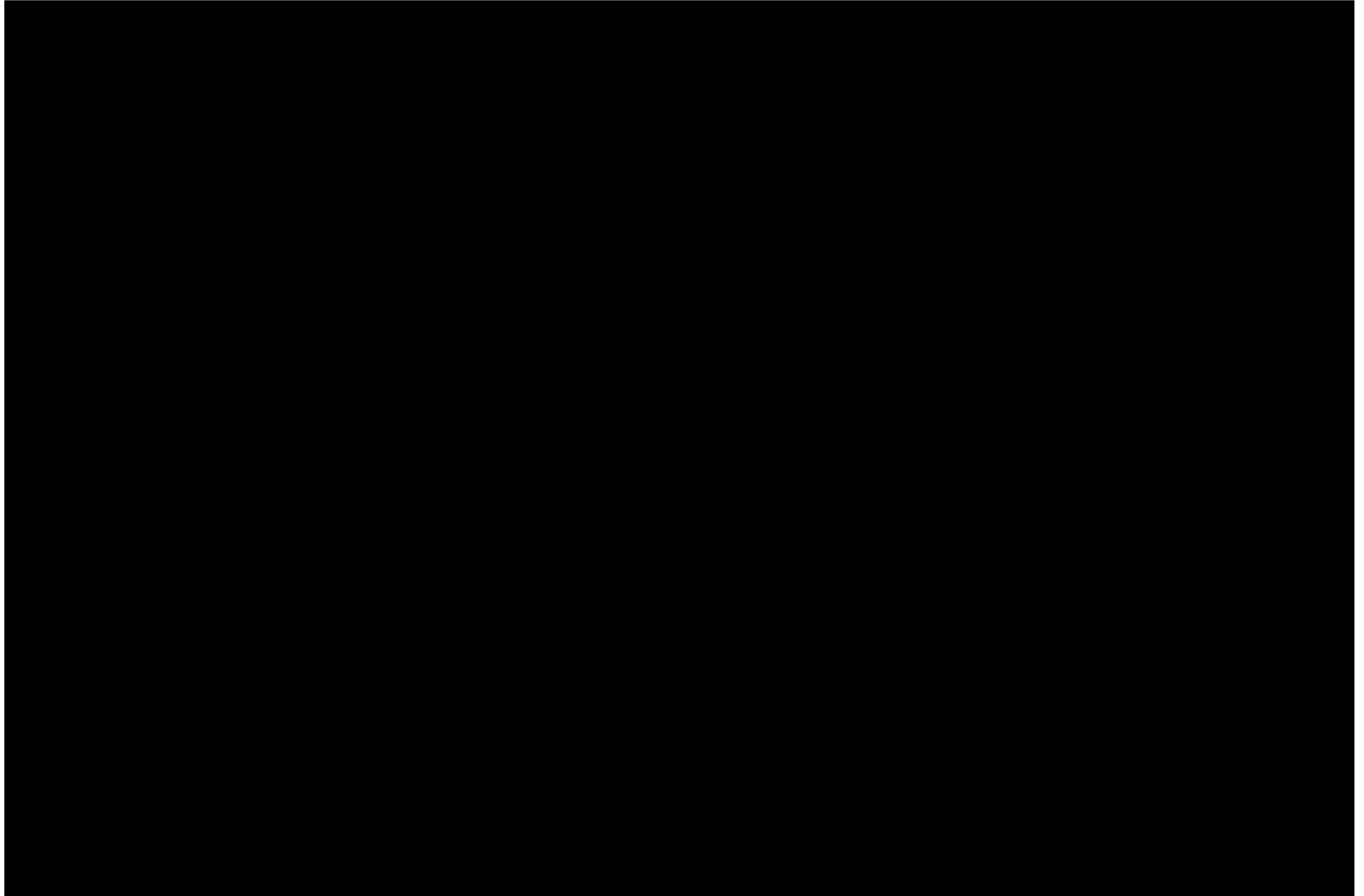


Exhibit 4D

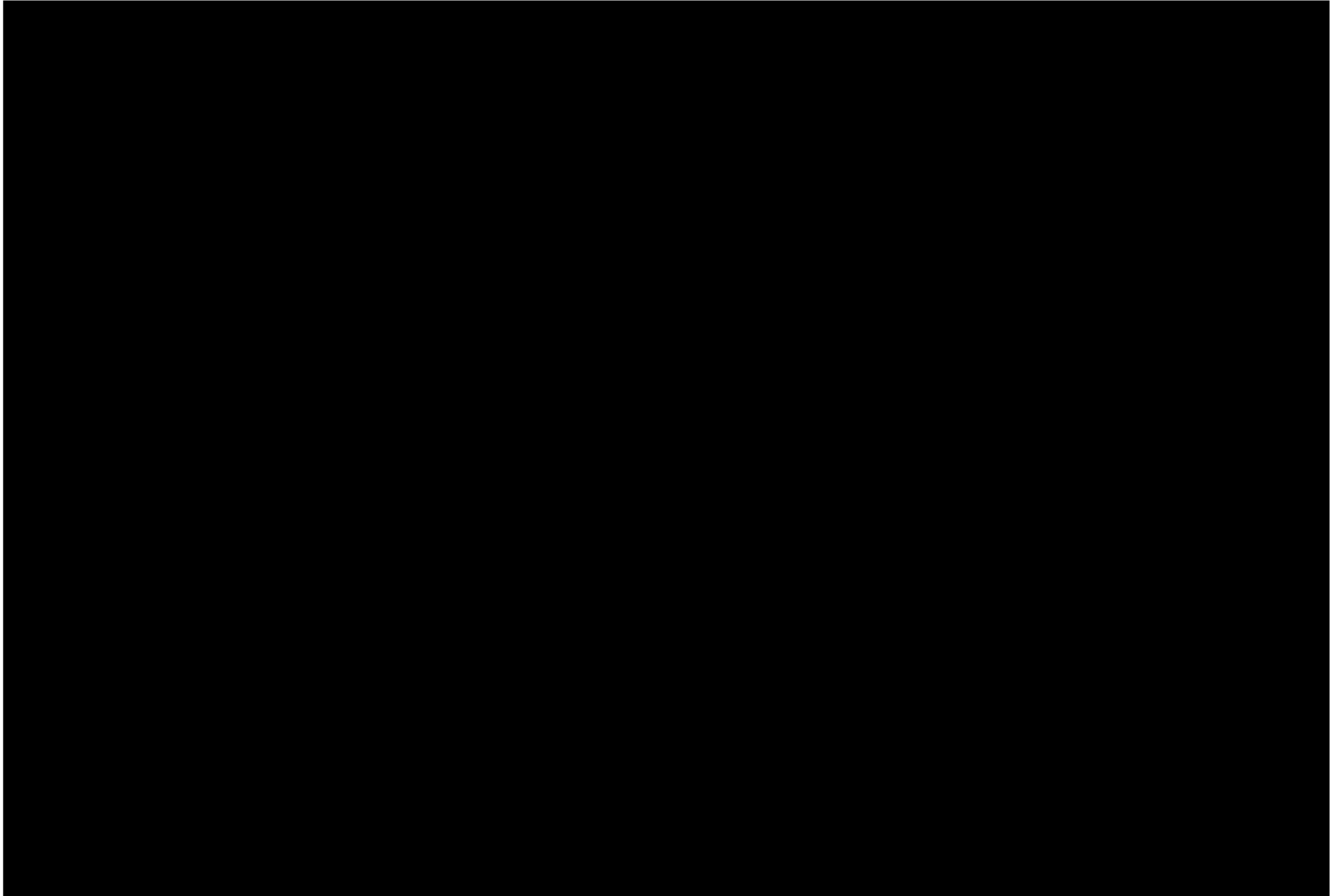


Exhibit 4E

